Restarting activity in the nucleus of PBC J2333.9-2343

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Fermi@10 Blazars and Beyond

Half a Century of Blazars and Beyond

11-15 June 2018 *Torino - Italy*

Europe/Rome timezone

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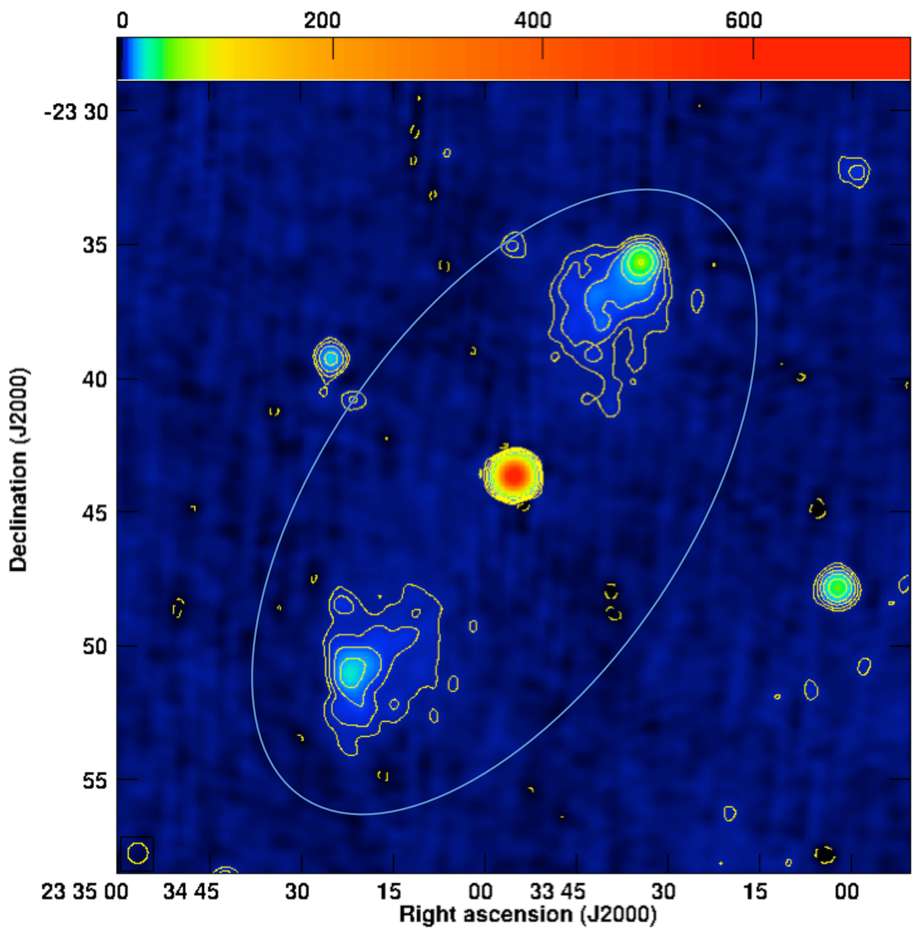
Francesca Panessa, Marcello Giroletti, Gabriele Ghisellini, Loredana Bassani, Nicola Masetti, Giustina Vietri, Enrico Piconcelli, Vharam Chavushayan, Lorenzo Monaco, Ivo Saviane, Mirjana Povic, Gabriele Bruni, Pietro Ubertini, Angela Bazzano, Sara Cazzoli, Angela Malizia

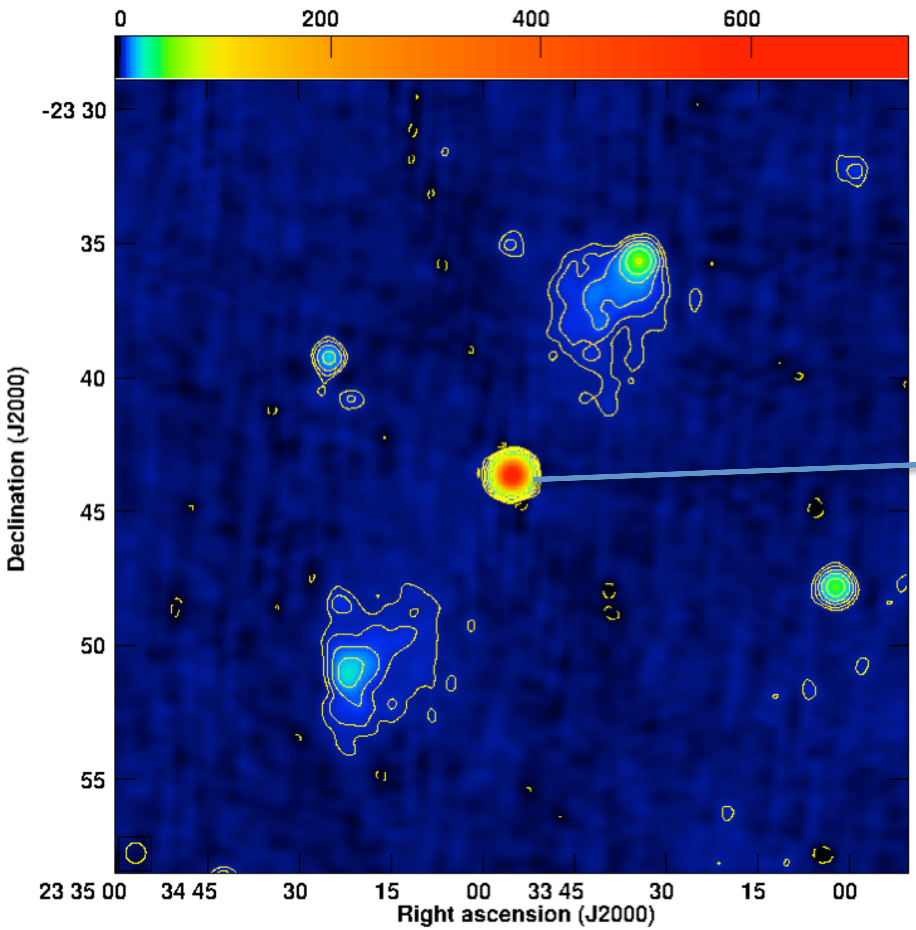
PBC J2333.9-2343

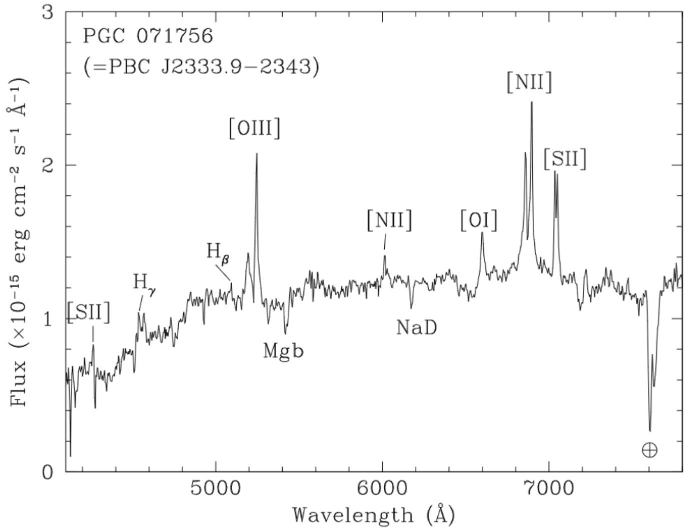


Giant Radio Galaxy (Bassani et al. 2016)

- 22' → 1150 kpc (PA~139°)

PBC J2333.9-2343

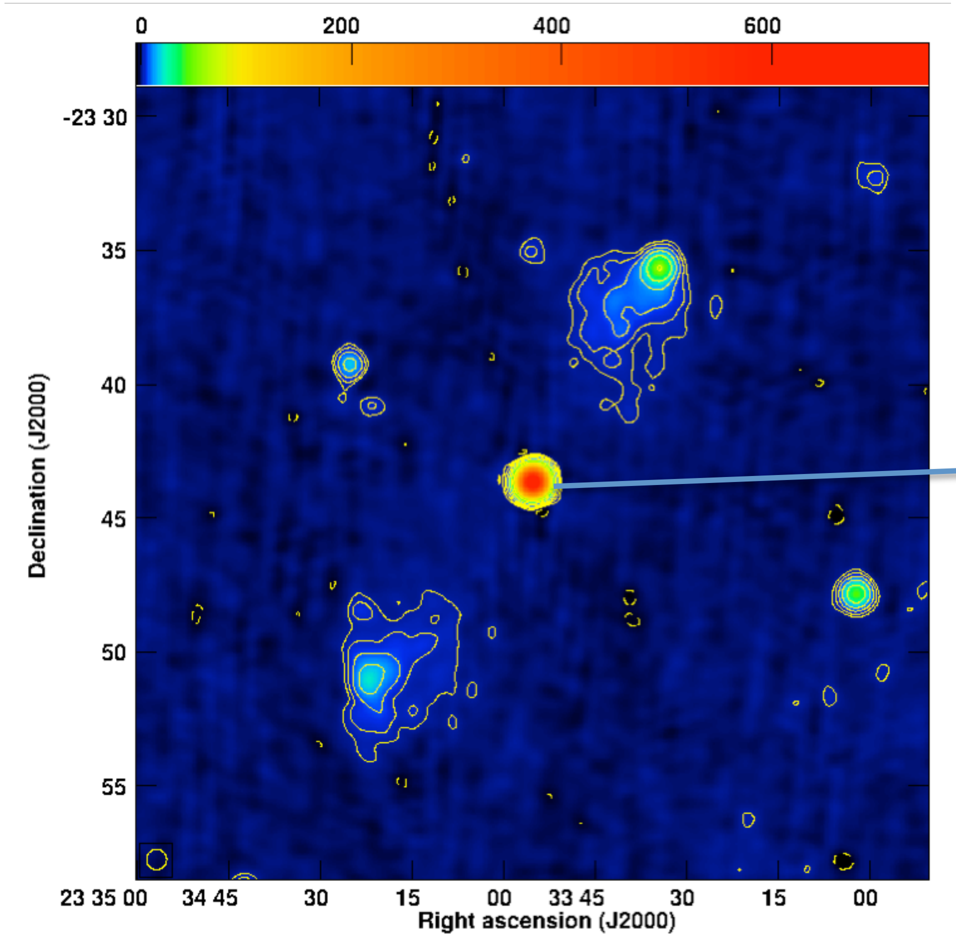




Classified as Seyfert 2 in the optical

→ z= 0.0475 (Parisi et al. 2012)

PBC J2333.9-2343



Swift/XRT observations

→ Unobscured at X-rays

→ type 1 ? (Parisi et al. 2012)

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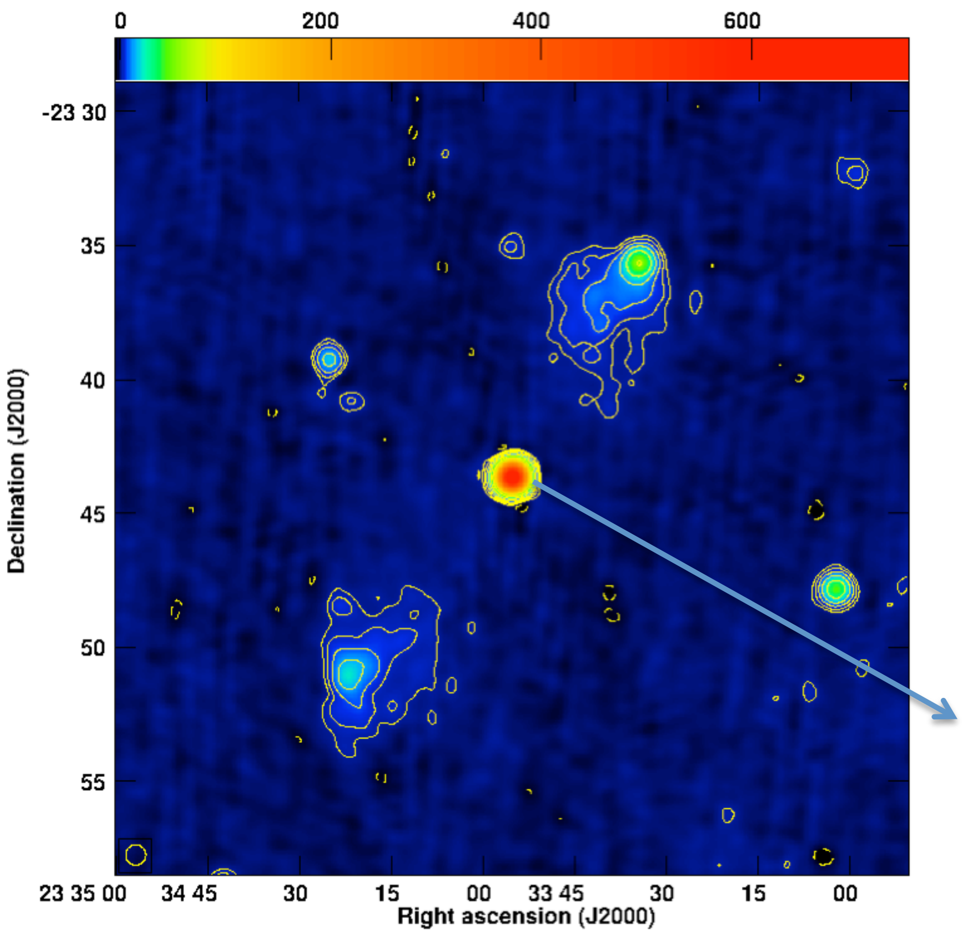


At radio frequencies:

→ ROMA BZCAT (Massaro et al. 2009)

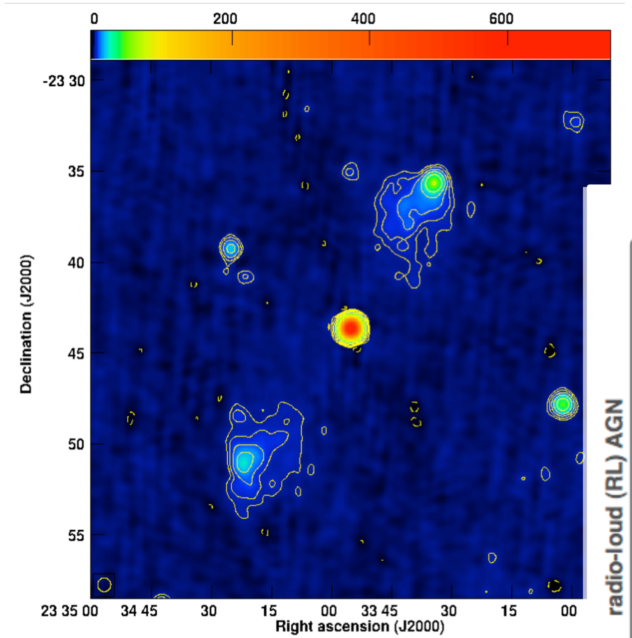
→ jet in VLBI at 8.4 GHz (Ojha et al. 2004)

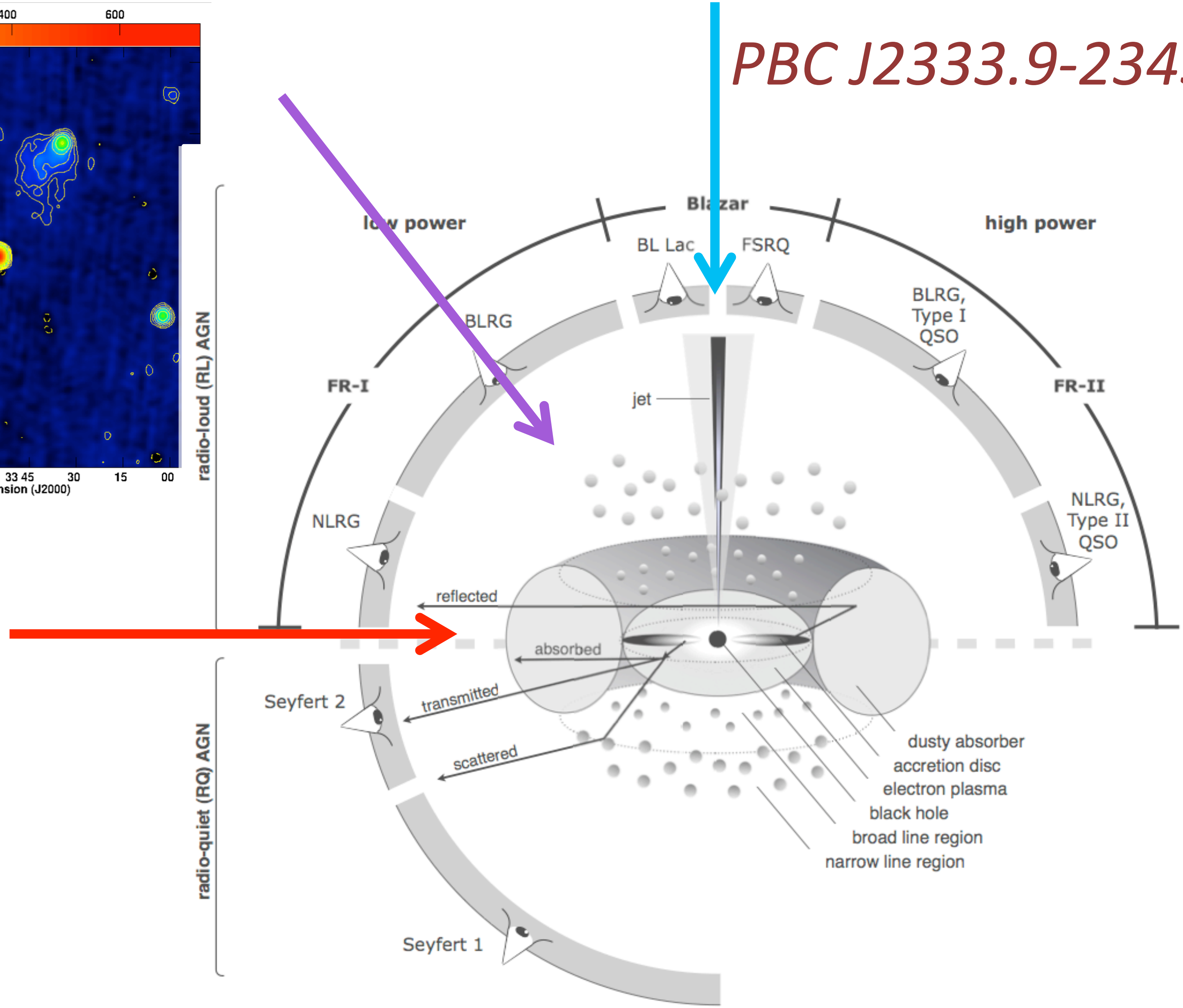
→ Blazar WISE colours (D'Abrusco et al. 2014)

→ Polarization (Ricci et al. 2004)

it seems a Blazar!

PBC J2333.9-2343



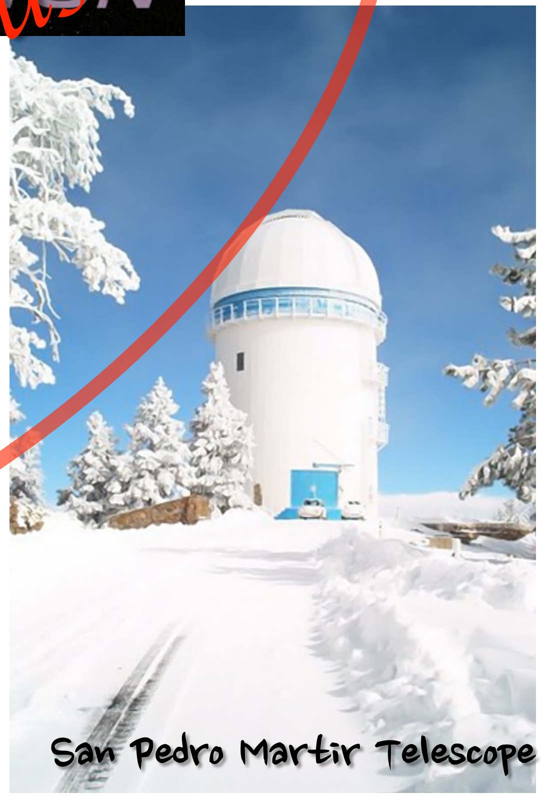


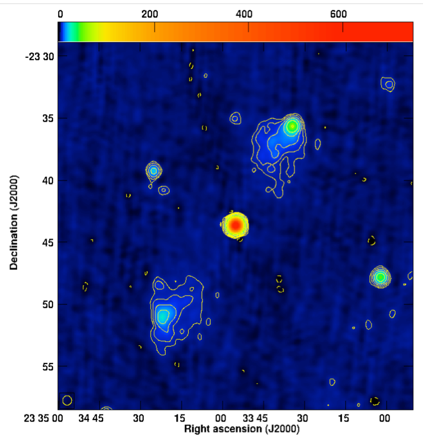
and ...a Giant Radio Galaxy


www.guarniero.nl
scale 1:4
XMM-NEWTON
Simultaneous!


The Very Long Baseline Array (VLBA)
Brewster, Wash.
Pie Town and
Los Alamos, N.M.
North Liberty, Iowa
Hancock, N.H.
Owens Valley, Calif.
Kitt Peak, Ariz.
Fort Davis, Texas
Mauna Kea, Hawaii
St. Croix, V.I.
1,000 km
1,000 miles

VLBA


San Pedro Martir Telescope



PBC J2333.9-2343

Two observations:

2015-05-15 (23 ksec)

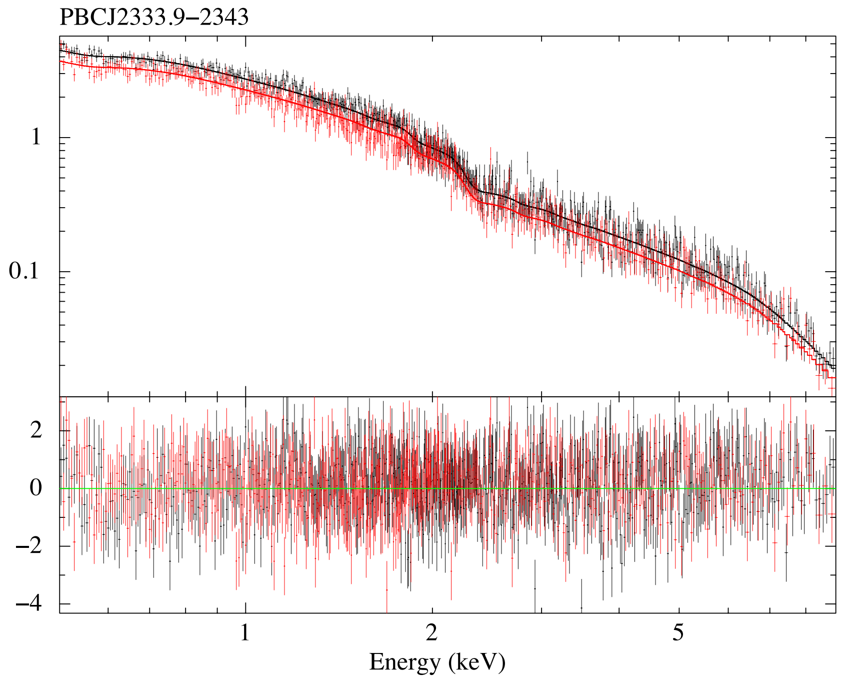
2015-11-17 (25 ksec)

Power law with varying normalization (16%):

Γ = 1.78[1.77-1.80]

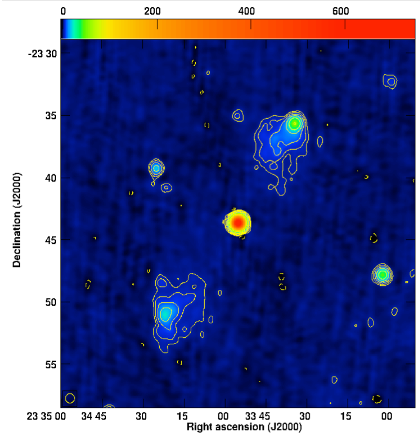
N_H = 2.4[2.1-2.7] x $10^{20}cm^{-2}$

logL(2-10 keV) ~ 43.7



Hernández-García et al. (2017)

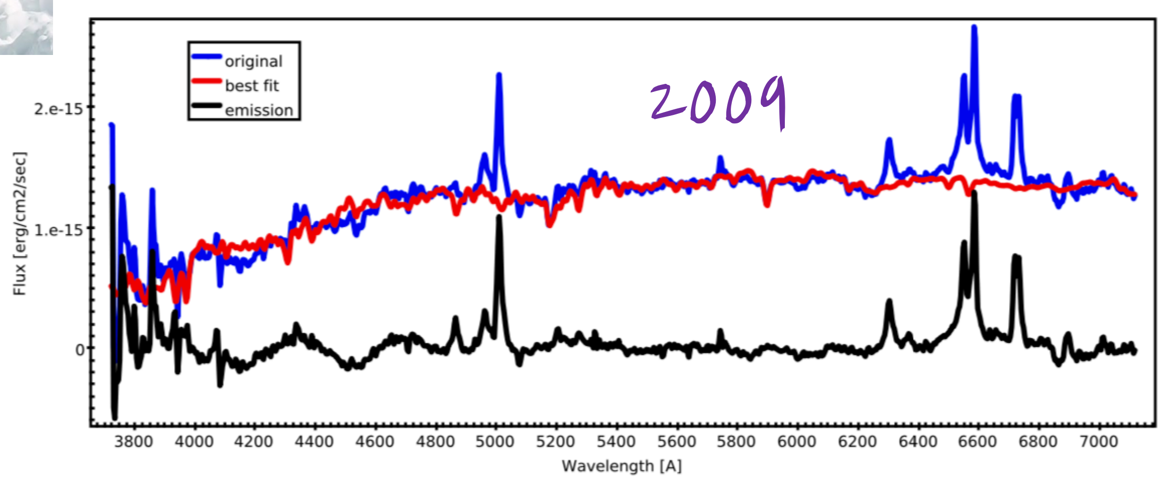
PBC J2333.9-2343



Two observations:

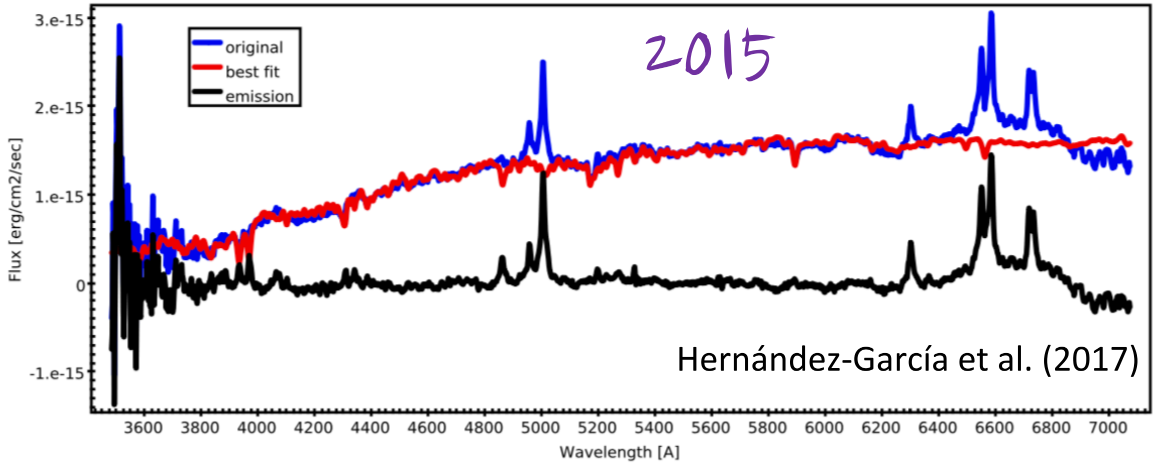
2009-09-18 (3.6 ksec)

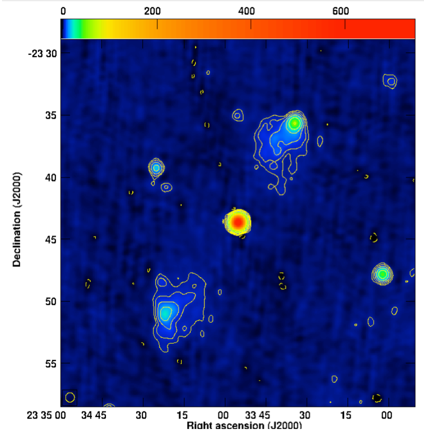
2015-11-07 (5.4 ksec)



After subtraction of the
10 Gyrs old galaxy population…

Broad H_α component
→ Seyfert 1.9

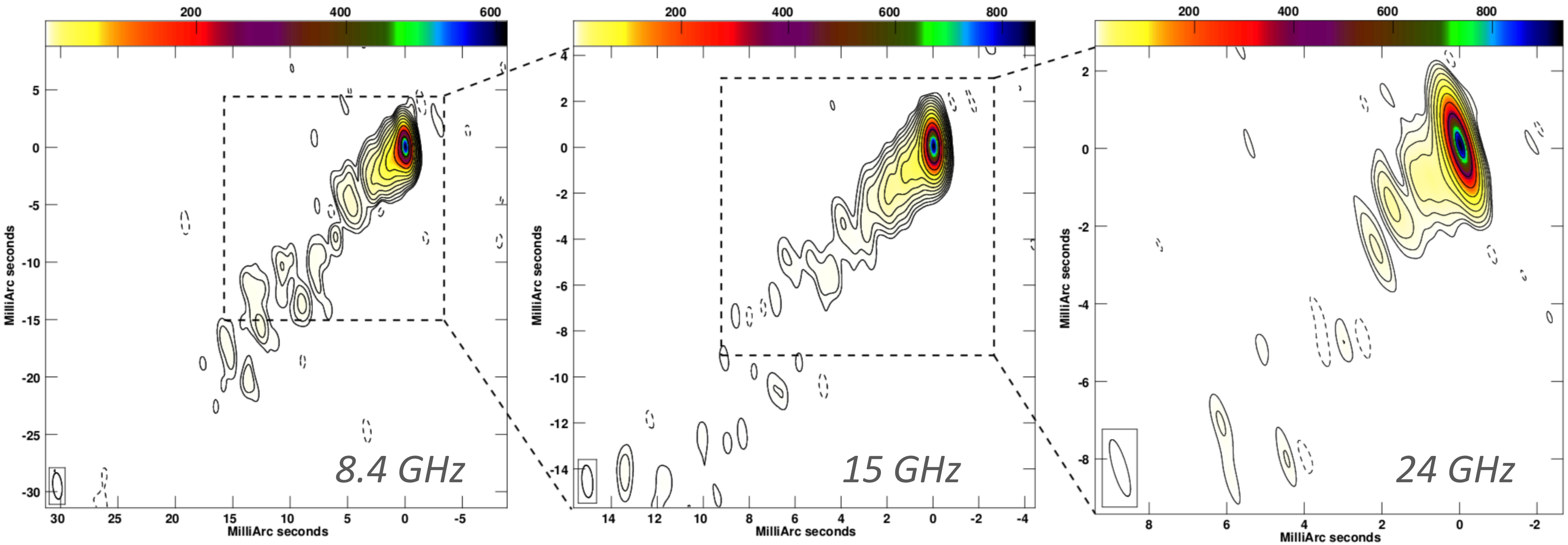




PBC J2333.9-2343

One observation (16/11/2015):
8.4 GHz (72 ksec)
15 GHz (119 ksec)
24 GHz (162 ksec)

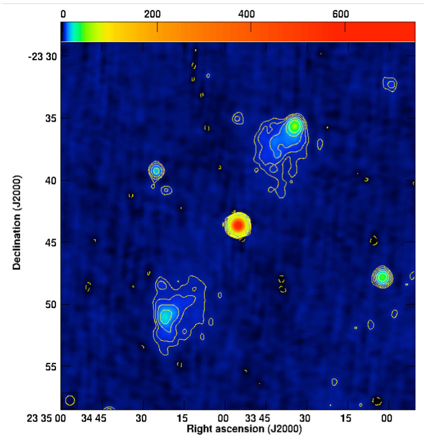
Hernández-García et al. (2017)



One sided jet:

- $\alpha_{j,8\text{-}15} = -0.5$
- Optically-thin synchrotron
- $\Theta < 40°$

- Compact, variable, bright core
  - $\alpha_c = 0.40$ - $S(\nu) \sim \nu^{+\alpha}$
  - Optically-thick regime
  - PA~133°



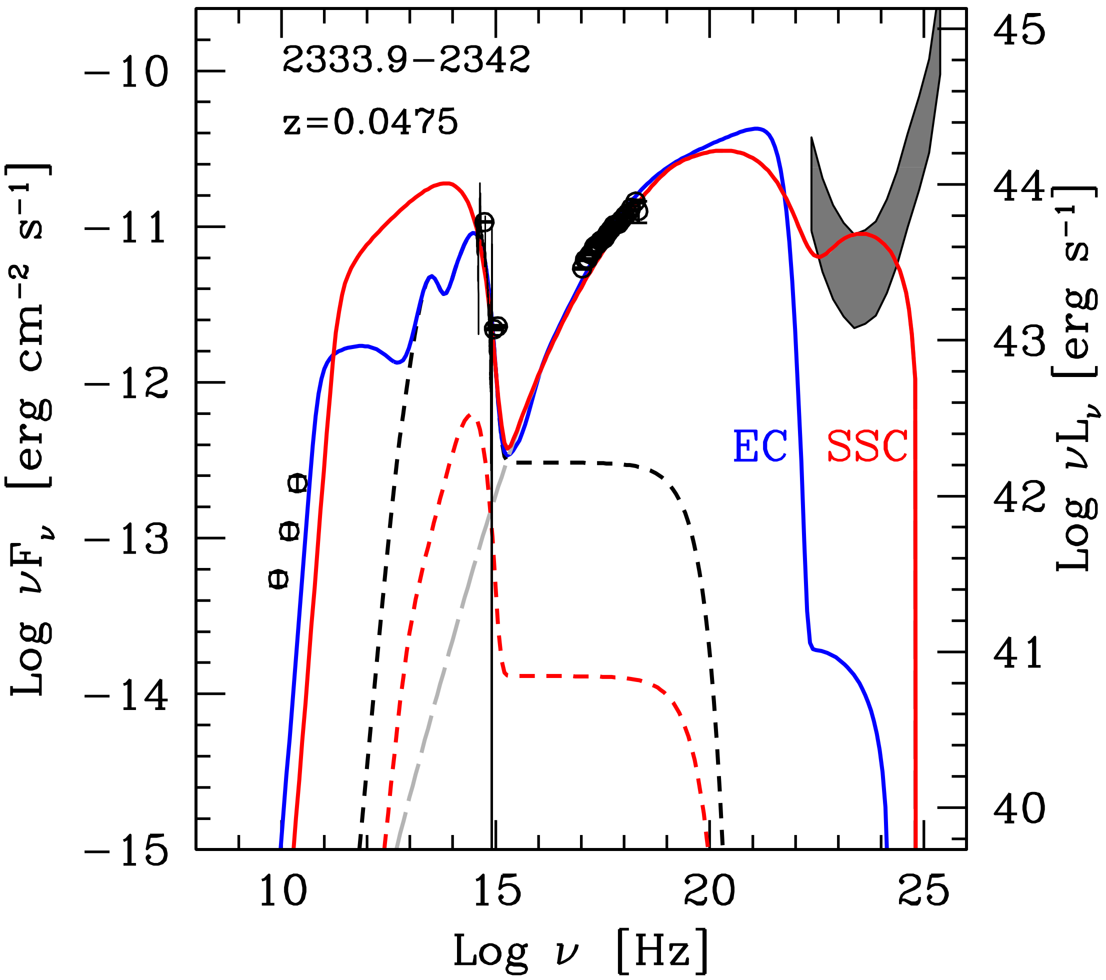
PBC J2333.9-2343

One-zone leptonic model
(Ghisellini & Tavecchio 2009)

SSC predicts a Fermi detection
→ EC

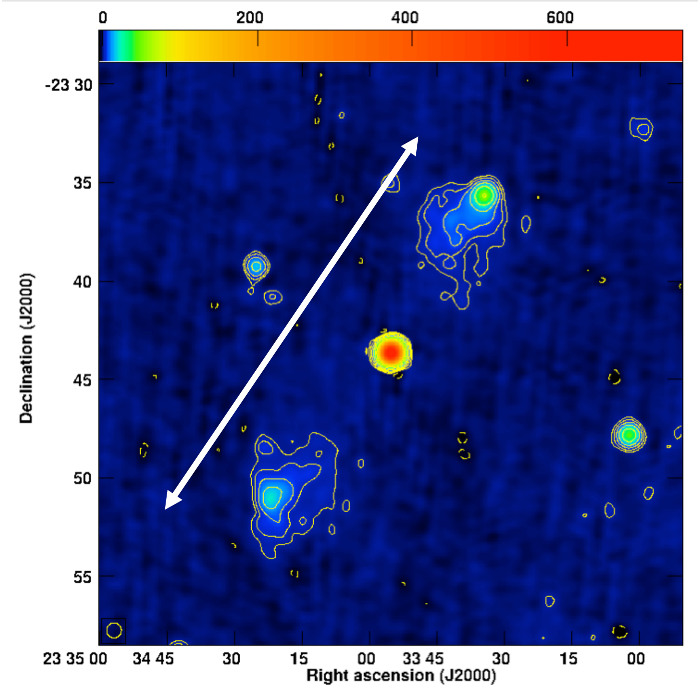
$M_{BH} \sim 10^8 M_\odot$
L_{disc}/L_{Edd}=1.3e-4

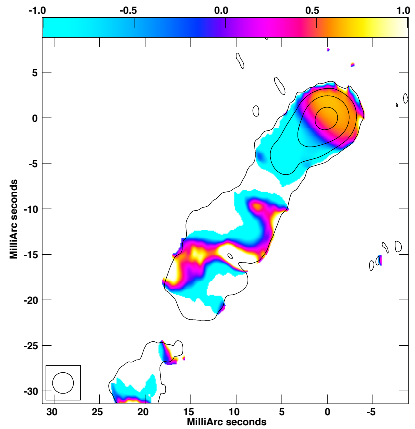
Jet observed at small angles:
Θ = 3-6°



Hernández-García et al. (2017)

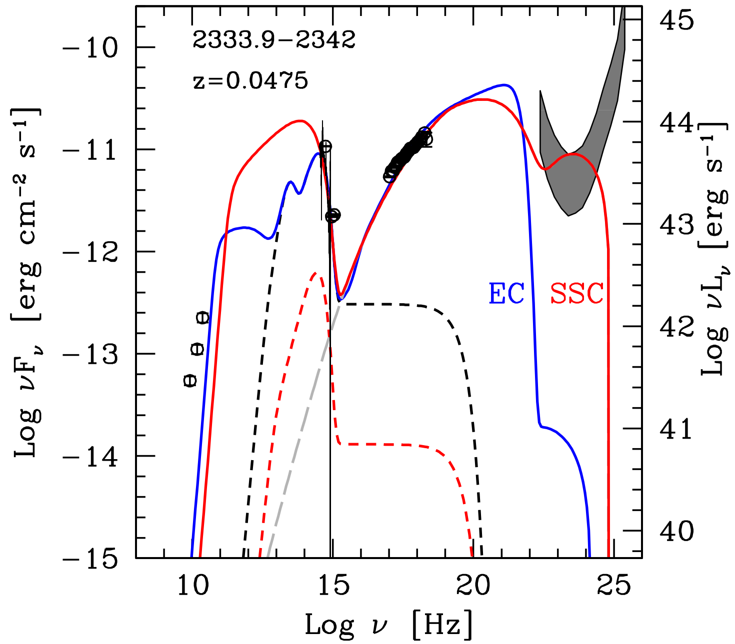
Hernandez-Garcia et al. 2017





→ small angle!

↑



Deprojection

→ Super giant radio galaxy?

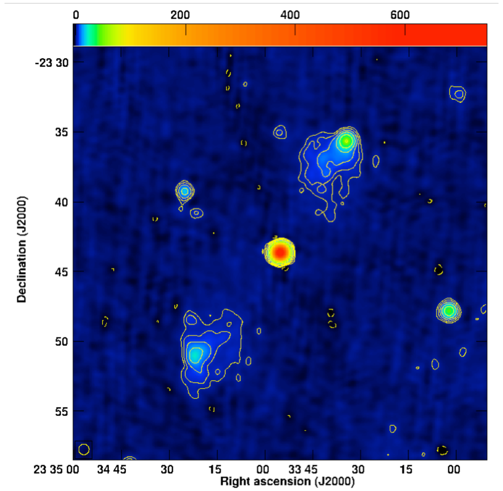
13 Mpc!!!!!!!

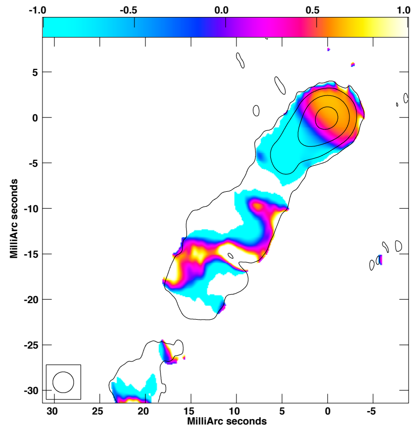
Largest giant radio galaxy 4.69 Mpc (Machalski et al. 2008)

THE REACTIVATING NUCLEUS OF PBC J2333.9-2343

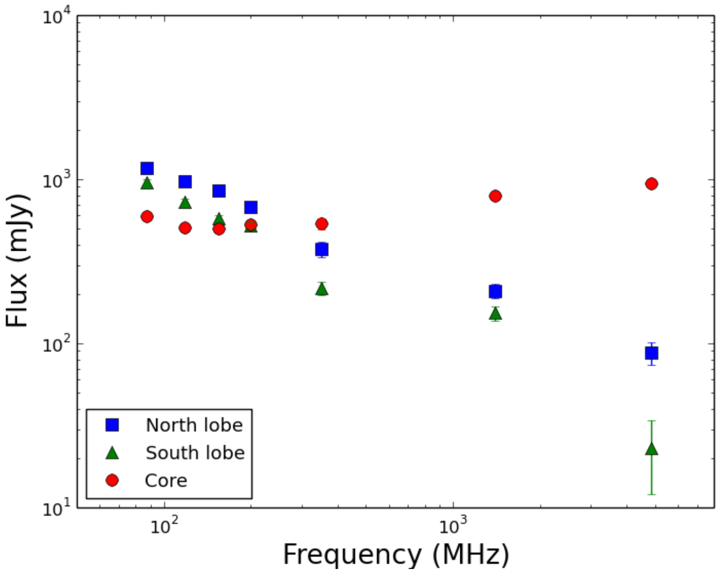
from giant radio galaxy to blazar!

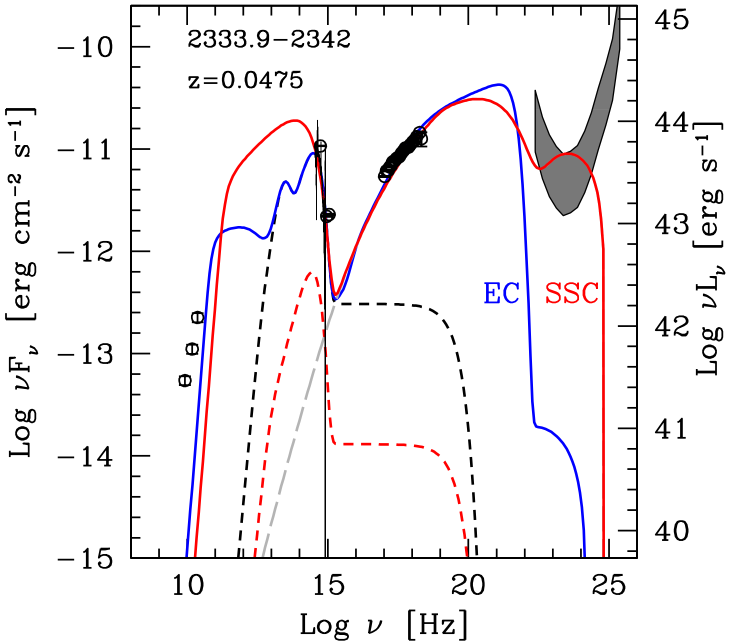
Hernandez-Garcia et al. 2017





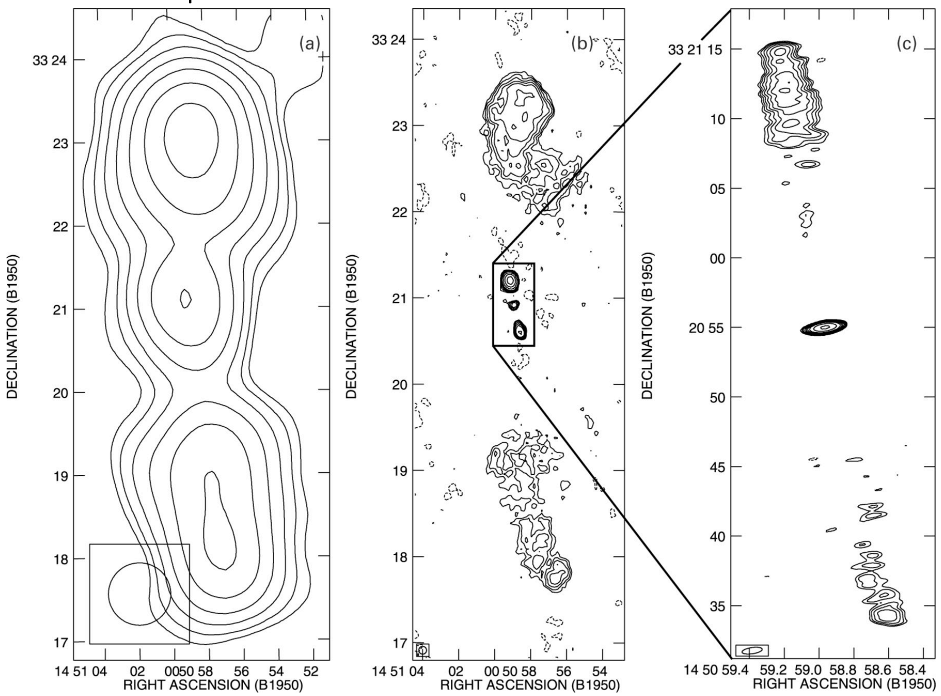
→ small angle!





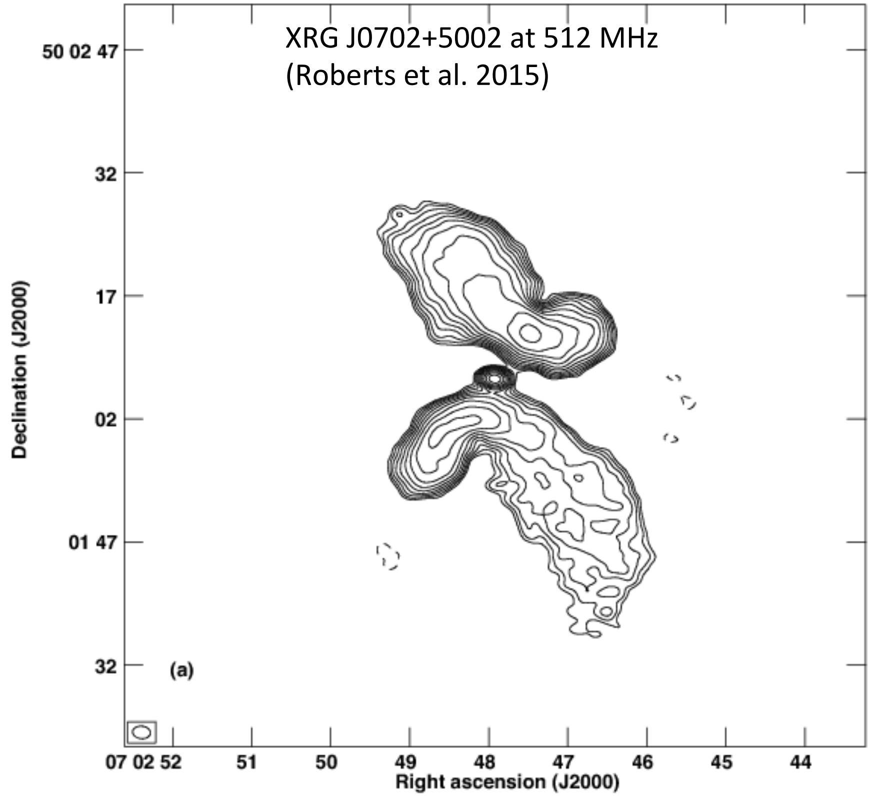
AGN RESTARTING ACTIVITY

Dennett-Thorpe et al. 2002



X-shaped radio-sources

Double-double radio-sources



PBC J2333.9-2343: an extreme case of reactivation

Jet orientation changes predicted by major mergers, minor interactions, instabilities in the accretion disc, etc. (e.g., Tchekhovskoy et al. 2016)

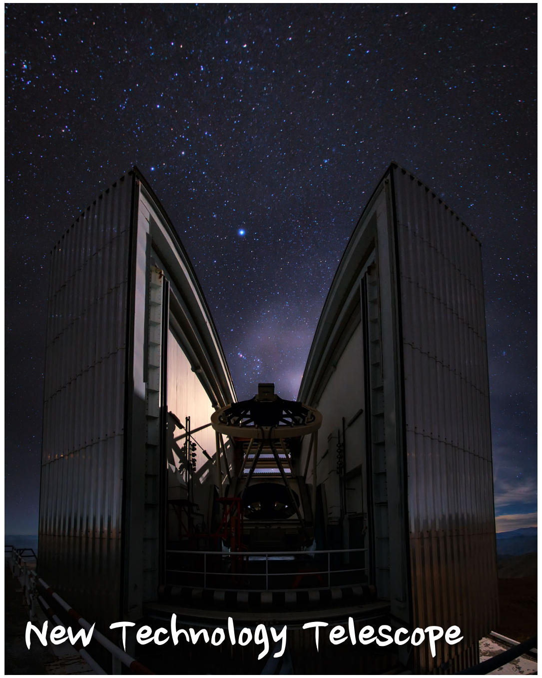
New Data!

Swift/XRT

→ *Eight spectra*

NTT,Chile

→ *One spectrum*



SPM, Mexico

→ *Three spectra*

NLR
BLR
Outflow
Total

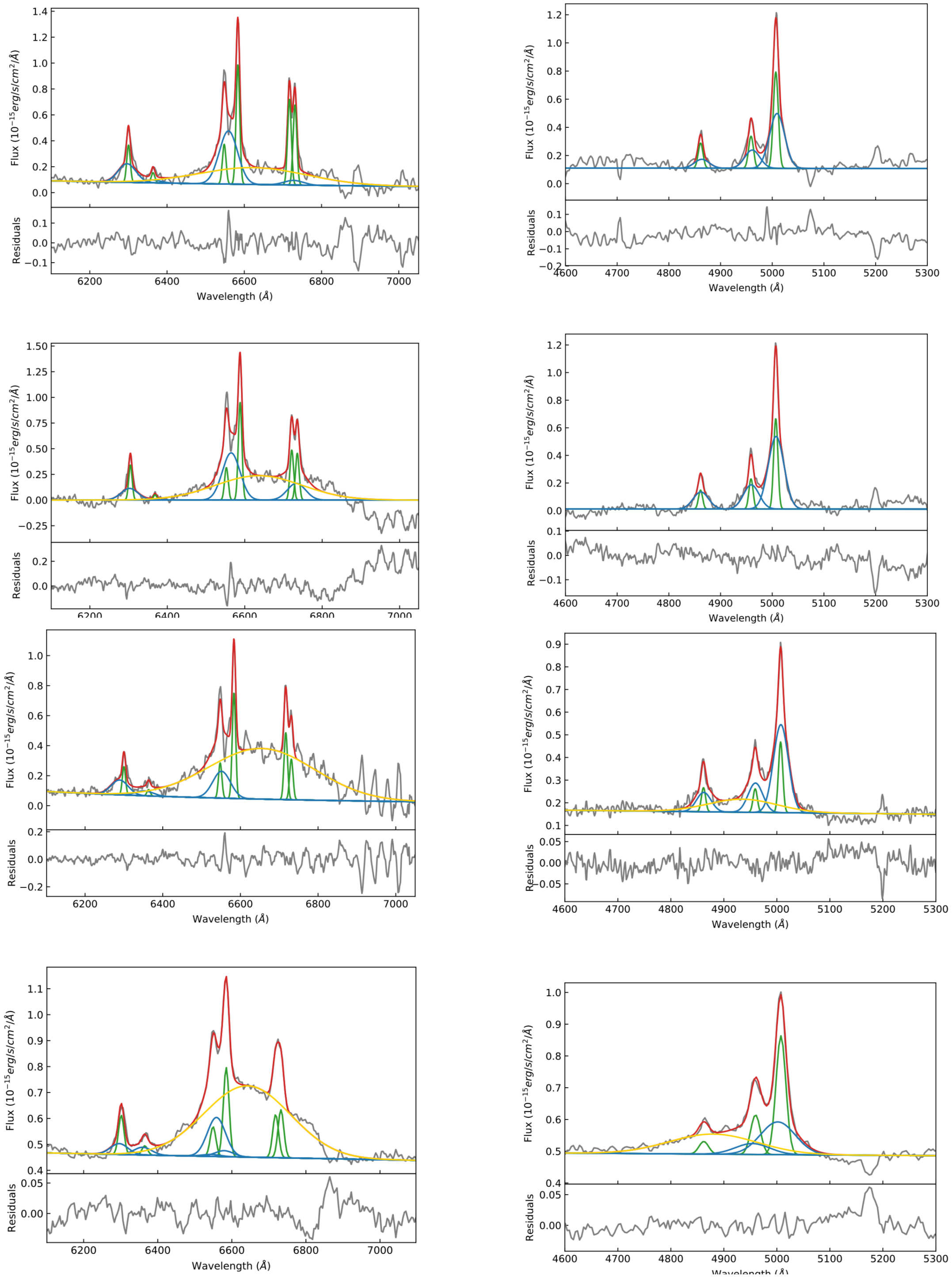
Variations in the broad lines

SPM, Mexico

2009

2015

2016

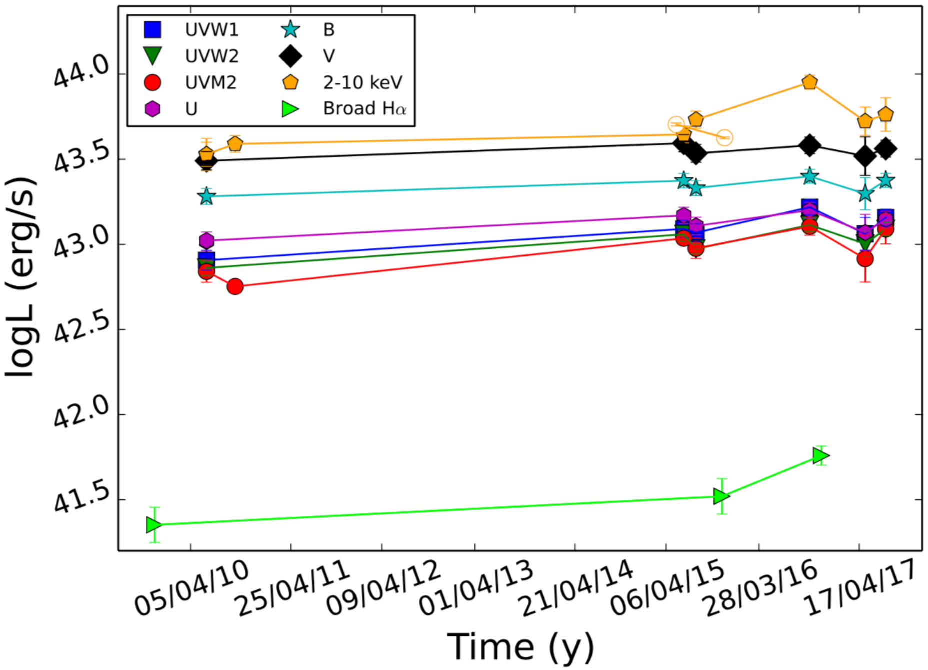


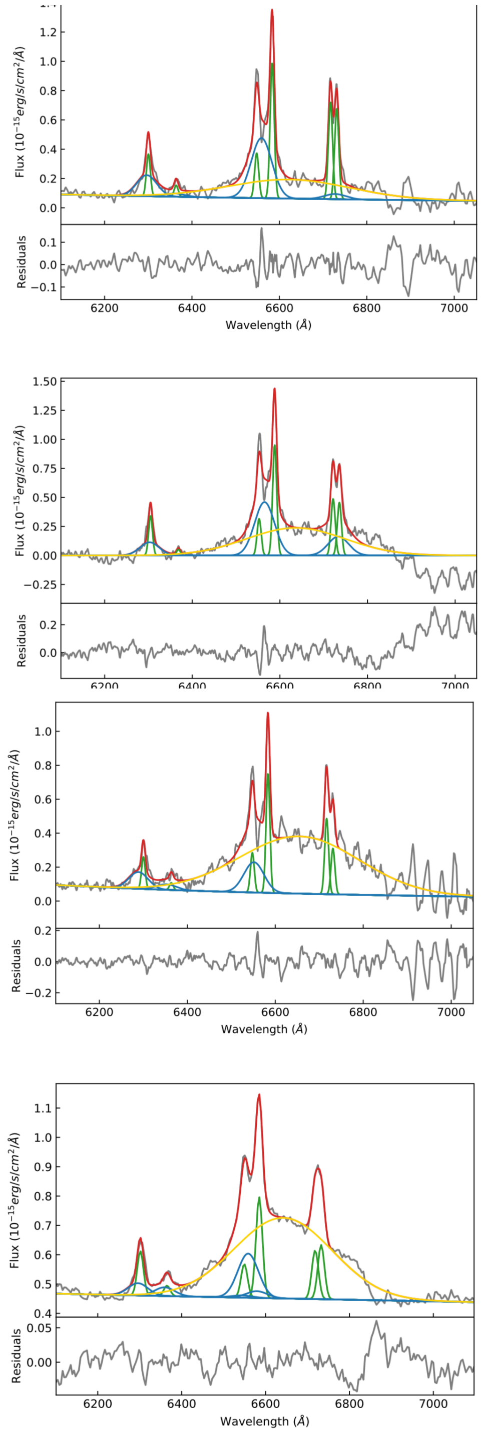
NTT, Chile

2016

Hernández-García et al. 2018

Hernández-García et al. 2018





…that follow variations in X-rays and opt-UV continuum (60% variations)

Changing type from Type 1.9 to Type 1.8
Jet – clouds interactions (Raiteri +2008, Leo-Tavares +2013)

Collisionally exited or shocked gas produce intense UV and soft X-rays

NLR
BLR
Outflow
Total

Brodened component in all narrow lines

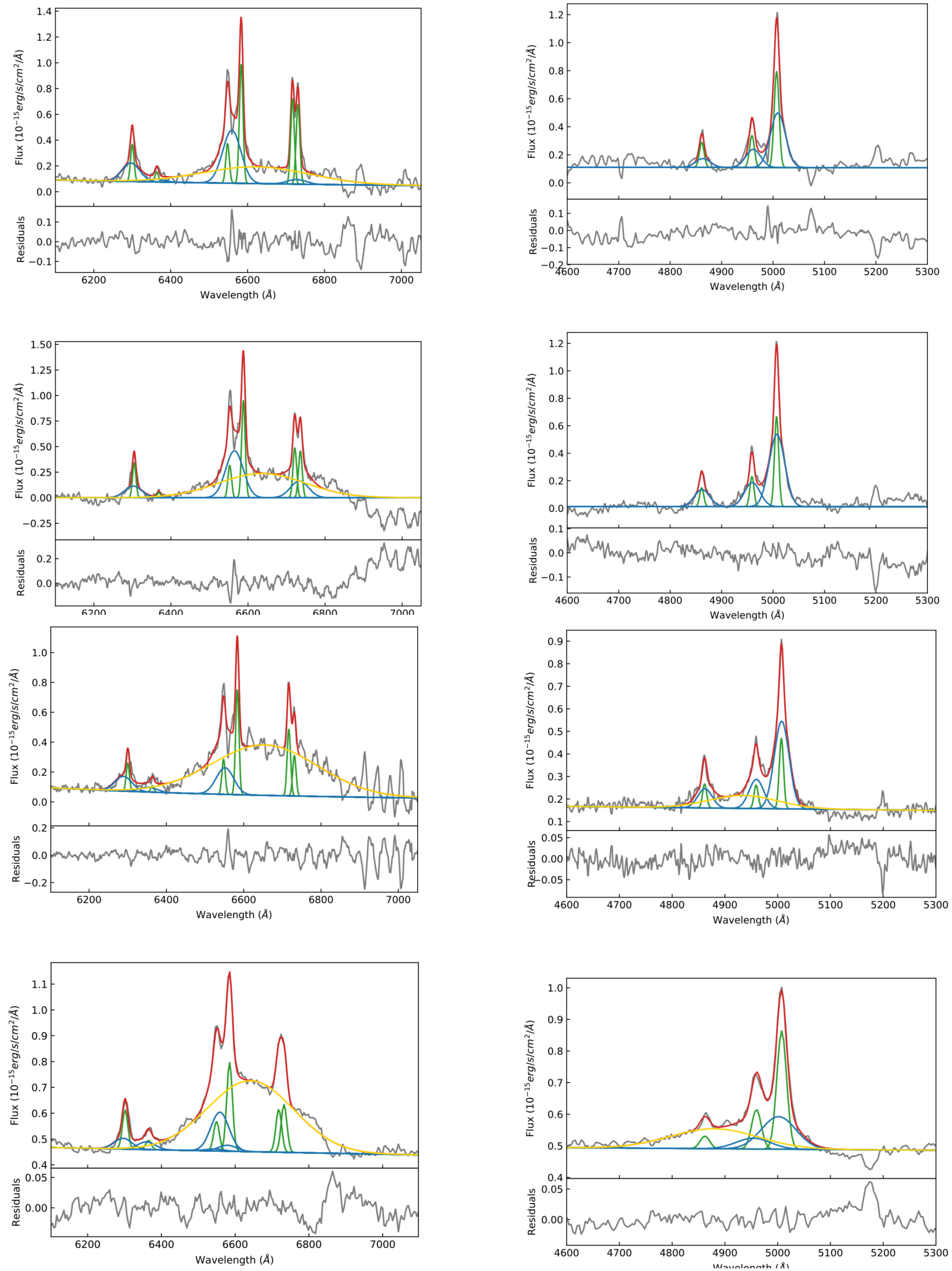
σ (OIII)=1919±301 km/s

modest blueshift of 347±187 km/s

maximum velocity of |Δv|+2σ=4230±660 km/s

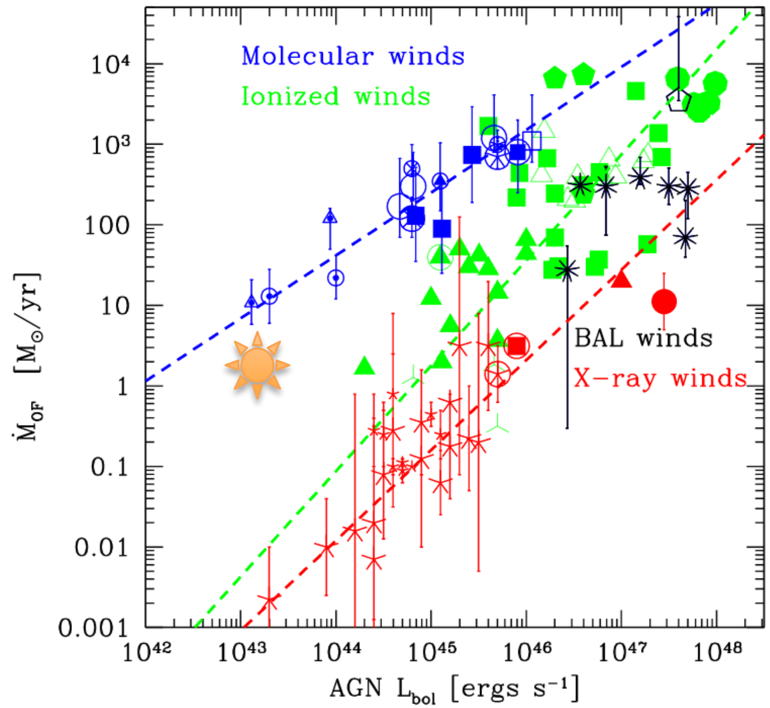
→ Large scale (NLR) outflow!

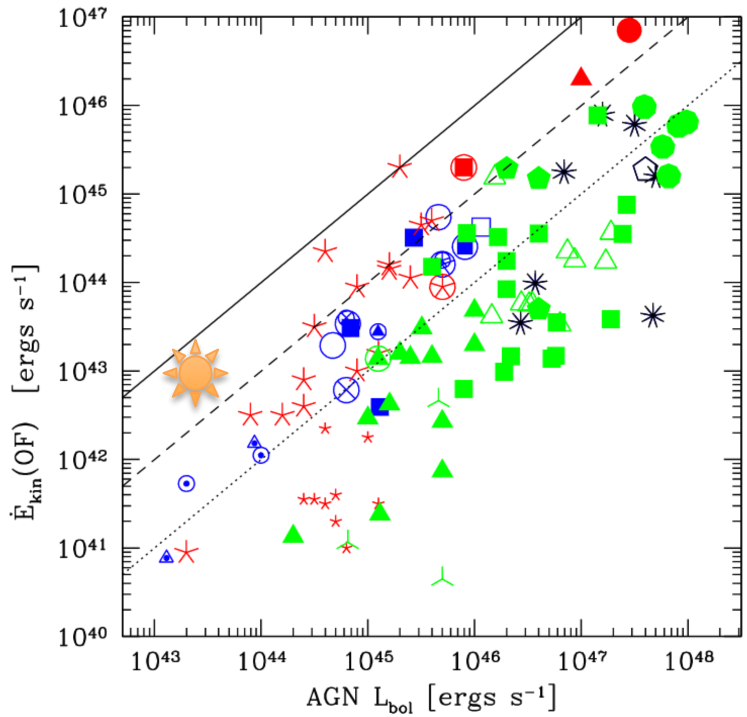
…2 sigma variability



Outflow parameters

Fiore et al. 2017

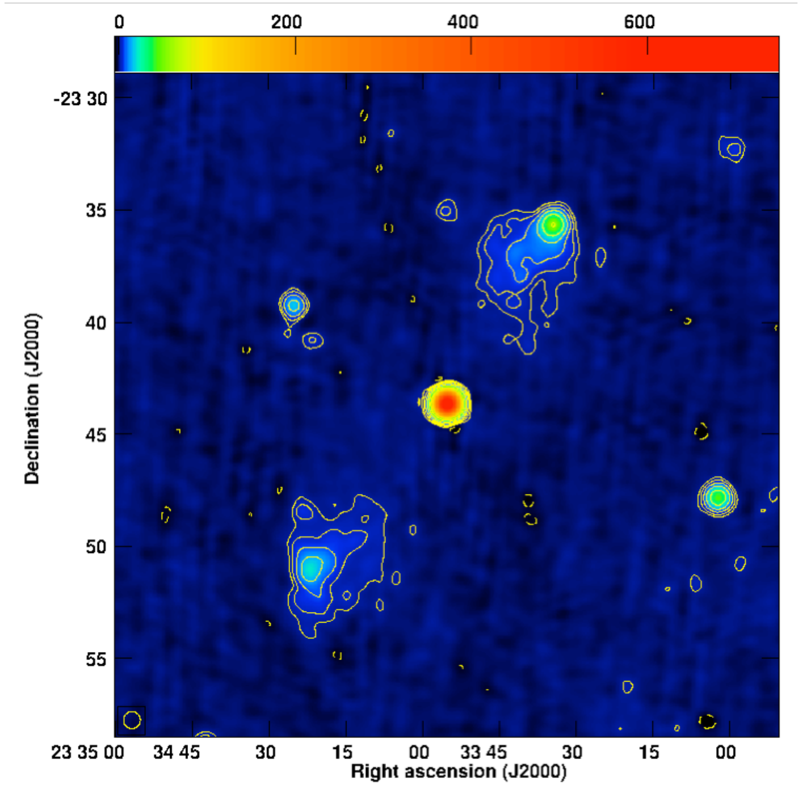




Mass outflow rate M(dot)=2.3 $M_\odot$/yr

Kinetic energy E_k=1.3x10^{43} erg/s

Outflow → interaction between the jet and the ambient medium (Couto et al. 2015, Emonts et al. 2005)



PBC J2333.9-2343 in summary:

Blazar core in a giant radio galaxy

→ Restarting activity + jet re-orentation?

Broad lines variable and narrow broadened components

→ jet-cloud interaction

Keep monitoring....
(New VLBA, GMRT, Effelsberg, Swift/XRT, optical...)

Thank you!

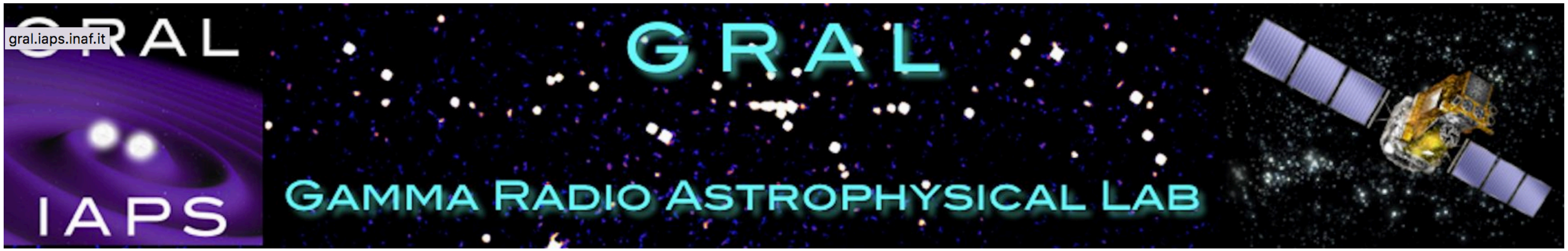

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Table 5. Adopted parameters for the jet models.

	M	$L_{\rm d}$	$L_{\rm d}/L_{\rm Edd}$	$R_{\rm diss}$	$R_{\rm BLR}$	$R_{\rm torus}$	$P'_{\rm e,jet,45}$	B	Γ	θ_v
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EC	3.0e9	0.047	1.3e–4	360	22	540	1e–3	0.14	10	3
SSC	–	–	–	90	–	–	7e–3	0.17	13	6

Notes. Column 1: model type, Col. 2: black hole mass in solar masses, Col. 3: disc luminosity in units of 10^{45} erg s^{-1}, Col. 4: disc luminosity in units of the Eddington luminosity, Col. 5: distance of the dissipation region from the black hole, in units of 10^{15} cm, Col. 6: size of the BLR, in units of 10^{15} cm, Col. 7: size of the torus, in units of 10^{15} cm, Col. 8: power injected in the jet in relativistic electrons, calculated in the comoving frame, in units of 10^{45} erg s^{-1}, Col. 9: magnetic field in G, Col. 10: bulk Lorentz factor, Col. 11: viewing angle in degrees.

Given our aim, the most important and robust result is that the observed level of radio emission and X-ray flux and slope can be reproduced only if the jet is observed at small, 3–6° viewing angles. At larger angles the SED cannot be well-reproduced. In particular, the Doppler factor, hence the flux enhancement, decreases sufficiently to require impossibly large intrinsic, meaning comoving, luminosity to account for the observed data. In addition, larger angles imply an increasing importance of the second order Compton scattering, which contributes in the gamma-ray band with a flux that should become visible by Fermi/LAT. Nevertheless, high-energy data (*Swift*/BAT, *NuSTAR*, INTEGRAL, *Fermi*) would be useful to better constrain our model parameters, in particular θ_v.

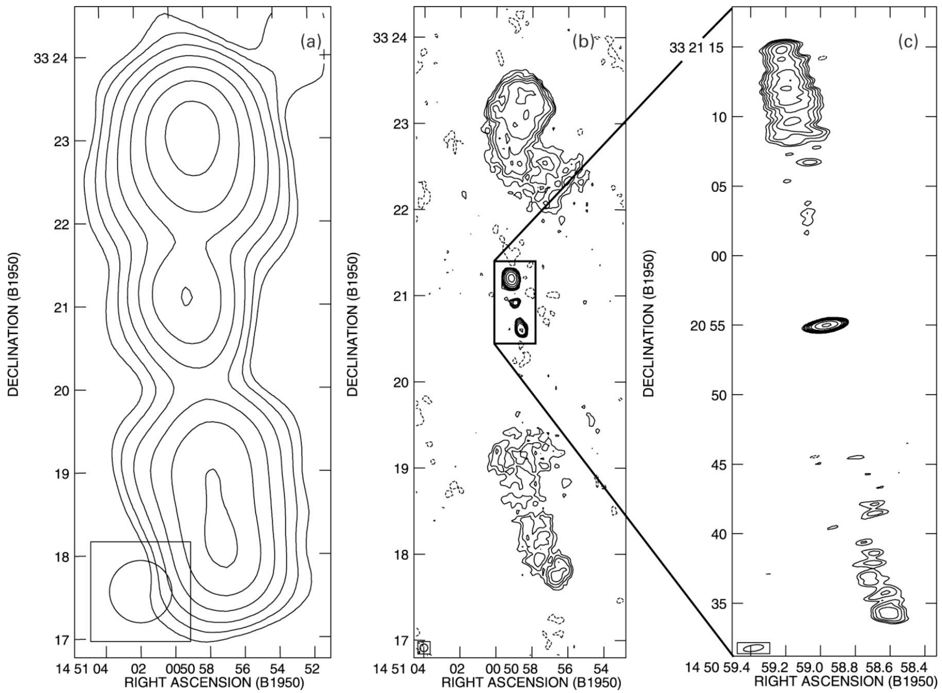
Table 1. Line fitting of the optical spectra of PBC J2333.9-2343.

Notes. For each spectrum, the signal to noise (S/N) of the continuum estimated in the 5650-5750 Å region, where no emission or absorption lines are present, the reduced chi-square and degrees of freedom (d.o.f.) of the spectral fits for the [OIII]-Hβ/Hα-[NII] regions, respectively, and the seeing for each night are presented. From the fourth line on, for each line the centroid wavelength, λ, in Å, shift respect to the NLR, $\Delta\lambda$, in km s^{-1}, line width, σ, in km s^{-1}, and fluxes, F, in units of 10^{-15} cm^{-2} s^{-1} Å^{-1}, are presented. The reported errors are those derived from the fit. The σ values have been corrected for instrumental broadening.

Line (1)	Parameter (2)	SPM(2009) (3)	SPM(2015) (4)	SPM(2016) (5)	ESO (2016) (6)
Spectrum	S/N	39	43	39	66
	$\chi_r^2/d.o.f$	0.9/1.0	0.8/1.0	1.3/1.2	1.1/1.0
	Seeing (arcsec)	2.5	2.6	2.5	1.2
$[OIII]_{outflow}$	λ	5009.3±0.8	5007.4±0.3	5007.6±0.2	5001.8±3.1
	$\Delta\lambda$	144±49	36±19	30±13	-347±187
	σ	850±60	880±30	803±24	1919±301
	F	13.8±2.0	19.4±1.1	13.1±0.6	8.3±1.9
Hα_{broad}	λ	6622.9±6.2	6636.0±6.7	6654.9±3.0	6642.3±2.7
	$\Delta\lambda$	2738±283	3337±306	4201±137	3625±123
	σ	6340±283	5120±238	6235±183	5325±101
	F	45±3	66±5	115±5	80±2
Hβ_{broad}	λ	-	-	4935.0±6.3	4879.7±21.9
	$\Delta\lambda$	-	-	4567±389	1154±1352
	σ	-	-	4005±259	5110±1062
	F	-	-	9±1	13±4

AGN RESTARTING ACTIVITY

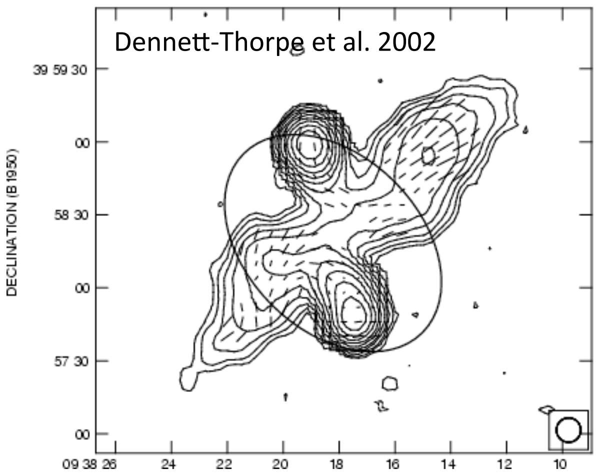
Double-double radio-sources Schoenmakers et al. 2000



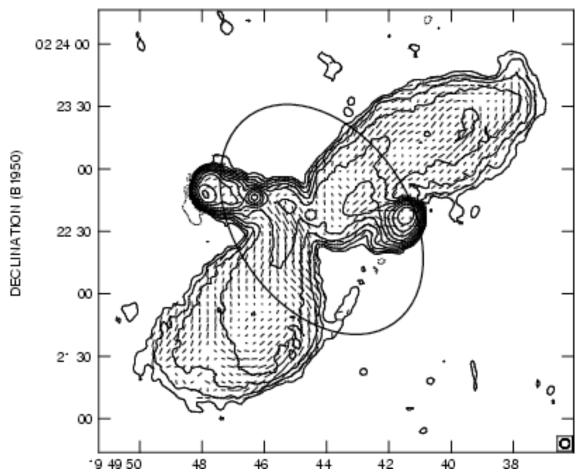
PBC J2333.9-2343: an extreme case of reactivation

X-shaped radio-sources

3C 223.1



3C 403



Jet orientation changes predicted by major mergers, minor interactions, instabilities in the accretion disc (e.g., Tchekhovskoy et al. 2016)